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DR. N. GOPALAKRISHNAN

(Scientist & Hon. Director IISH)

**Indian Institute of Scientific Heritage
Thiruvananthapuram - 695 018**

Heritage Publication Series - 66

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DISCOVERY AND USE OF ZERO

गायत्रे षड्संख्यामर्धेऽपनीते द्वयङ्के अवशिष्ट स्रयस्तेषु
रूपमपनीय द्वयङ्काद्यः शून्यं स्थाप्यम् ।।

*Gaayatbre shadsankhyaamardhef apaneetbe dvayanke
avashistasthrayastheskuroopamapaneeya dvayankaadha: soonyam sthaapyam*

In gayatri chandas, one pada has six letters. When this number is made half, it becomes three (i.e. the pada can be divided into two). Remove one from three and make it half to get one. Remove one from it, thus gets the zero (Soonya).

PINGALACHARYA IN CHANDA SASTRA 200 B.C.

CALCULATIONS WITH ZERO

विकारामायान्ति धनऋणखानि न शून्य संयोग वियोगतस्तु
शून्याद्धि शुद्धं स्वमृणं क्षयं स्वं वधादिना खं खहरं विभक्ताः

*Vikaaramaayaanthi dhanarunakhaani na soonya samyoga
viyogatbasthu soonyaaddhi suddham swamrunam kshayam
swam vadhaadinaa kham khaharam vibhaktbaa:*

Nothing happens (to the number) when a positive or negative number is added with 0. When +ve and -ve numbers are subtracted from 0, the +ve number becomes negative and -ve number becomes +ve. When multiplied with 0, the values of both +ve and -ve numbers become 0, when divided by 0, it becomes infinity (khahara).

SRIPATI IN SIDDHANTHA SEKHARA 1039 AD

DISCOVERY OF PLACE VALUES - I

यथा एकरेखा शतस्थाने शतं दशस्थाने दशैवं चैकस्थाने
यथा च एकत्वेपि स्त्री-माता च उच्यते दुहिता स्वसा च इति

*Yathaa ekarekhaa shatsthaane shatam dashasthaane dashaivaan chaikasthaane yathaa
cha ekatvepi stree maataa cha uchryate duhitaa swasaa cha itih*

In the unit place the digit has the same value, in 10th place, 10 times the value and in 100th place 100 times the value, is given.

VYASA BHASHAYA TO YOGA SUTRA 650 AD

DISCOVERY OF PLACE VALUES - II

यथाचैकापि रेखा स्थानान्यत्वेन निविशमानैक
दश शत सहस्रादि शब्द प्रत्यय भेदमनुभवति

*Yatbaachaikaapi rekha sthaananyatvena nivisamaanaika
dasa satha sahasraadi sabda prathyaya bhedbamanubhavatbi*

One and the same numerical sign when occupying different places is conceived as measuring 1, 10, 100, 1000 etc.

SANKARACHARYA VEDANTA SUTRA BHASHAYA

KNOWLEDGE ON INFINITY

अस्मिन् विकारः खहरे न राशावपि प्रवेष्टेष्वपि निःसृतेषु
बहुष्वपि स्याल्लयसृष्टिकाले नन्ते च्युते भूतगणेषु यद्धत्

*Asmin vikara khabare na raasaavapi praveshteshvapi ni:
sruthesbu babushvapi syaallaya srushtikaalefnantbef chyutbe
bbootbaganesbu yaddbath*

Nothing happens to the (huge number) infinity, when any number enters (added) or leaves (subtrated) the infinity. During pralaya many things get dissolved in Mahavishnu and after pralaya, during srushti all those things get out of him. This happens without affecting the lord himself. Like that, whatever number is added to infinity or whatever is subtracted from it, the infinity remains unchanged.

BRAHMAGUPTHA IN BRAHMASPHUTA SIDDHANTA 600 AD
BHAKARACHARYA II - BEEJAGANITA 1148 AD

USE OF AVERAGE VALUES

गणयित्वा विस्तारं बहुषुस्थानेषु तध्युतिर्भाज्य
स्थानकमित्या सममितिरेवं दैर्घ्यं च वेधे च

*Ganayithva visthaaram babushusthanesbu tbadhyuthirbhaayyaa
sthaanakamityaa samamitirevam dairgye cha vedbe cha*

(For length, breadth and depth) the measurements should be taken at many places and the sum should be divided by the number of times (places) the measurement is taken.

BHASKARACHARYA II IN ULAVATI 1150 AD

USE OF FRACTIONS

द्रुमार्धत्रिलवद्वयस्य सुमते पादत्रयं यद्भवेत् तत् पञ्चांशक
षोडशांशचरणः संप्रार्थितेनार्थिना । दत्तो येन वराटकाः
कति कदर्येणार्पितास्तेन मे ब्रूहि त्वं यदि वेत्सि वत्स गणित
जार्ति प्रभगाभिधाम् ।।

*Drammaardha thrilavadvayasya sumatbe paadathrayam
yadbhaveth that panchaamsaka sboda saamsa charana:
sampsraarthithenaa- rtbinaa datto yenavaraatakaa: kathi
kadaryenarpithastena me broobithvum yadi vetsi vatsaganitha
jaathim prabhagaabhidhaam*

One man has given to a beggar fraction of 1 dramma
(a unit of money). That fraction is one fourth of
the one sixth of one fifth of the three fourth of the
two third of the half of a dramma. Then tell how
much kowdi (a unit fraction of the amount dramma)
was given to the beggar?

BHASKARACHARYA I - ARYABHATEEYA BHASHAYA 628 AD

USE OF RATIO AND PROPORTION

अष्टौ दान्तास्त्रयो दम्या इति गावः प्रकीर्तिताः ।
एकाग्रस्य सहस्रस्य कति दान्ताः कतीतरे ।।

*Ashtow daantbaa sbryo damyaa ithi gaava: prakeertbi thaa:
ekaagrasya sahasrasya kathi daantbaa: katbeetharai:*

(Out of 11 cattle) Eight are tamed and 3 are to be
tamed and (how many are) to be tamed) if the
number of cows is 1001?

BHASKARACHARYA I - ARYABHATEEYA BHASHAYA 628 AD

PERMUTATIONS AND COMBINATION - I

कटुकतिक्त कषायाम्ललवण मधुरैः सखे रसैः षड्भिः ।
विदधाति सूपकारो व्यञ्जनमाचक्ष्य कति भेदम् ॥

*Katukathiktha kashayaamla lavana madhurai: sakhe rasai: shadbhi:
vidadhaati soopakaaro vyanchanamaachakshya kati bhedam*

Friend, a cook prepared varieties of food with 6 savours: pungent, bitter, astringent, acid, saline and sweet. Say what is the possible number of varieties of food that can be made with these savours.

SRIDHARACHARYA IN PATIGANTTA 230 AD

PERMUTATIONS AND COMBINATION - II

पाशाङ्कुशाहि डमरुक कपाल शूलैः खड्वाङ्गशक्ति
शरघापयुतैर्भवन्ति । अन्योन्य हस्त कलितैः कति मूर्तिभेदाः
शंभोर्हरिरिव गदारि सरोज शंखचक्रैः ॥

*Paasankusaahi damarooka kapaala soolai: khadvangasakthi
sara chaapayutbairbhavanthi anyonya hastha kalithai: kati
moorthibhedaa: sambho haririva gadaari saroja sankachakrai:*

Pasa, ankusa, serpent, damaru, kapala, soola, khatvanga, sakti, chapa, sara with these (ten) items how many permutations and combinations are possible for Lord Siva. Similarly with the four items, sanku, chakra, gadha and padma holding in the hands, how many combinations are possible for Lord Vishnu?

BHASKARACHARYA II IN LILAVATI 1114 AD

PARTNERSHIP AND SHARES

समवायकास्तु वणिजः पञ्चैकैकोत्तराधि मूलधनाः ।

लाभः सहस्रसंख्यो यद कस्मै तत्र किं देयम् ।।

Samavaayakaasthu vanija: panchaikottharaadhi mooladbanaa: laabha: sabasra sankhyo vada kasmai tathra kim deyam

Five partners collaborate in a business. The capital invested by them are (in the ratio) one and the same number increasing successively by one (i.e 1,2,3,4, & 5) respectively. Profit that accrued amounts to 1000. Say what should be given to whom.

BHASKARACHARYA I - IN ARYABHATEEYA BHASHYA 628 AD

LOANS AND INTERESTS

कुटुम्बार्थमशक्तेन गृहीतं व्याधितेन वा उपप्लावनिमित्तं
च विद्यादापत्कृतं तत् । कन्यावैवाहिकं चैव प्रेतकार्येषु यत्कृतं
एतत् सर्वं प्रदातव्यं कुटुम्बेन कृतं प्रभो ।।

Kutumbaarthamasakthena grubeetham vyaadhithena va upaplava nimiththam cha vidyaathaapalkrutham thath kanyaavaivahikam chaiva prethakaaryesbu yathkrutham ethath sarvam pradaatbavyam kutumbena krutham prabho

Loans are taken for meeting the expenditure connected with economic problems due to family burden, health problems, treatment, education, expenditure during accident, marriage of daughter, for performing rituals connected with the demise of the family members, etc.

VISHNUSMRUTHI 100 BC

INTEREST CALCULATION

मासेन शतस्य फलं पञ्चैको भाव्यकेऽर्धमय वृत्तो ।

लेखकपादो वर्षे पञ्चाधिक नवशतीमिश्रम् ॥

*Maasena sathasya phalam pancchaiko bhavyake ardhamaya vruttho
lekhakapaado varsho pancchaadika navasathimeesram*

The rate of interest being 5% per month, the commission of surety 1% per month, fee for accountant 1/2% and charges of the scribe 1/4% per month, certain sum amounts to 905 a year. Find the capital, the interest and the shares of the surety?

RULES OF CHARGING INTEREST

अथ उत्तमर्णः अधमर्णाद्यथा दत्तमर्थं गृह्णीयात् ।

द्विकं त्रिकं चतुष्कं पञ्चकं च शतं प्रतिमासं ॥

*Atha utthamarna: adhamarnaadyattha dattamartham
grubheeyaath dvikam trikam chatvushkam panchakam cha
satham prathimaasam*

The loans can be given and taken between borrower and lender. Generally charged interest rates are 2, 3, 4, or 5% per month.

सपादपणा धर्म्या मासवृद्धिः ।

पणशतस्य पञ्चपणा व्यावहारिकी

*Sa paadapanaa dharmyaa maasavrudhi: panassathasya
panchapanaa vyaavaharikee*

Reasonable (dharmic) rate of interest is 1.25% per month (i.e 15% per annum) on the transactions with common man for non commercial purposes. But for commercial purposes (for making profit out of it) interest rate can be 5% per month.

RULES OF BODIES IN MOTION

भक्ते विलोमविवरे गतियोगेनानुलोमविवरे द्वौ ।

गत्यन्तरेण लब्धौ द्वियोगकालावतीतैष्यौ ॥

*Bhaktbe vilomavivare gatbiyogenaanulomavivare dvow
gathyantharena labdow dviyogakaalaavatbeethaishyow*

Whenever two bodies are travelling in the opposite directions, the distance between them is to be divided by the sum of their speeds. If they move in the same direction, the distance is to be divided by the difference of their speeds. This gives the time required for meeting of the bodies or the time elapsed after meeting of the moving bodies.

ARYABHATA I - ARYABHATEEYA 499 AD

एकौ ना योजनान्यष्टौ यात्यन्यौ योजनद्वयम्

योजनानं शतं पन्थाः संगमः क्व गमागमे ॥

*Ekow naa yojananyashtow yaatbyanyo yojanadvayam
yojanaanaan satham pantbaa: sangama: kva gamaagame*

One man travels at 8 yojana speed per day. Another travels at 2 yojana per day, starting simultaneously from the same place. After reaching the destination, the first man comes back. If the length of the track is 100 yojana. Say where is the meeting place of the two? (One going forward and the other traveller returning).

SREEDHARACHARYA PATIGANITHA 920 AD

PROGRESSION OF THE TYPE

$$1^2 + 2^2 + 3^2 + 4^2 + \dots$$

सप्तानां अष्टानां सप्तदशानां चतुर्भुजाश्वितयः ।

एकविद्यानां वाच्यं पदस्तरास्ता हि वर्गाख्याः ॥

Saptanaanam ashtanaanam saptadasanaanam chatburbhujaaschitaya: ekavidyaanaam vaachyam padastaraasthaa hi vargaakhyaa:

There are (three pyramidal) piles on square bases having 7, 8 and 17 layers which are also squares. Say the number of units there in.

BHASKARACHARYA I - ARYABHATEYA BHASHYA 628 AD

PROGRESSION OF THE TYPE $1^3 + 2^3 + 3^3 + 4^3 +$

चतुरश्रघनश्वितयः पञ्चचतुर्नवस्तरा विनिर्देश्याः ।

एकावघटितास्ताः समचतुरश्रेष्टकाः क्रमशः ॥

Chaturasragbanaschitaya: panchachatburnavastaraa vinirdesyaa: ekaavaghatitthaasthaa: samachatbura sreshtakaa: kramasa:

There are three pyramidal piles having 5, 4 and 9 cuboidal layers. They are cuboidal bricks (of unit dimension) with one brick in the topmost layer. Find the number of bricks used in them.

BHASKARACHARYA I - ARYABHATEYA BHASHYA 628 AD

PROGRESSION OF THE TYPE

$$\Sigma n + \Sigma n^2 + \Sigma n^3 + \Sigma n^4$$

द्विगुणतसैकपदघ्नं सैकपदं प (द) दलद्वतं भवति ।

*Dvigunitba saikapadagbnam saikapadam
pa(da)dalabrutbam bbavatbi*

The number of terms plus one, as multiplied by twice the number of terms plus one, being (further) multiplied by half the number of terms.

संकलितकृतिघनानां संकलितसमासमानां मे कथय ।
षण्णां सखे पदानां गणयित्वा यदि विजानासि ॥

*Sankalitakrutibhavanaanaam sankalitasamaasamaanaam me
kathaya shannaam sakhe padaanaam ganayitvaa
yadivijaanaasi*

Friend, if you know, then say after calculation (i) the sum of successive sum of 6 natural numbers (ii) the sum of the squares of the first 6 natural numbers and (iii) the sum of the cubes of first 6 natural numbers

SREEDHARACHARYA - IN PATIGANTHA 900 AD

FIRST DEGREE INDETERMINATE EQUATION

मुद्गानां कुडवाः सप्त लभ्यन्ते नवभिः पणैः पणैः कुडव-
स्थार्धं तण्डुलानामवाप्यते । ततः पणत्रयं सार्धं गृहीत्वा $\frac{1}{2}$ शु
वणिङ्मम तण्डुलानां प्रयच्छांश मुद्गानां च द्विसङ्गुणम् ।।

*Mudgaanaam kudavaa: saptha labhyaante navabhi: pane:
panena kudavasyaardham tbandulaanaamavaapyathe thatha:
panatbrayam saardham grubeetbvaa fasu vaningmama
tbandulaanaam prayacchaamsa mudgaanaam cha
dvisangunam*

7 kudavas (unit of measurement) of mudga are obtained for 9 panas and $\frac{1}{2}$ kudava of rice is obtained for one pana. Then O! merchant take $3\frac{1}{2}$ panas and quickly give me one part of rice and two parts of mudga.

SREEDHARACHARYA - IN PATIGANITHA 900 AD

FIRST ORDER EQUATION - I

ये निर्जरा दिनदिनार्धं तृतीय षष्ठैः संपूरयन्ति हि पृथक्
पृथगेव मुक्ताः । वार्षी यदा युगपदेव सखे विमुक्तास्ते केन
वासरलयेन तदा वदाशु ।।

*Ye nirjaraa dinadinaardha tbrutheeya sbasbtai: sampoorayantbi
pruthak pruthakeva mukthaa: vaapeem yadaa yugapadeva
sakhe vimukthbaasthe kenavaasaralavena thadaa vadaasu*

By opening 4 inlets separately, one pond gets filled respectively within 1, $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{6}$ days. If all the four inlets are opened together, how much time (in fraction of the day) is required to fill the pond ?

BHASKARACHARYA II - IN LILVATI 1114 AD

FIRST ORDER EQUATION - II

नव गुलिका तप्त(च) रूपकसमासस्त्रयाणां (तु) गुलिकानां।

त्रयोदशानां च रूपकाणां तदा किं गुलिकामूल्यम्॥

Nava gulikaa saptha (cha) roopakasamaastbrayaanaam (tu) gulikaanaam tbrayodasaanaam cha roopakaanaam thadaa kim gulikaa moolyam

If 9 gulika and 7 rupaka are equal to 3 gulika and 13 rupaka, what is the price of one gulika? (the answer can be determined through the same method followed above)

SRIEDHARACHARYA PATIGANTHA 990 AD

EQUATIONS OF HIGHER ORDER- I

वानरकुलत्रिभागः स्वत्र्यंशसमन्वितः सरः प्रययौ।

मूलं च पिपासति द्वौ चूततले स्थितौ शेषौ॥

Vaanarakulatbrihbaga: svathryamsa samanvilita: sara: prayayow moolam cha pipaasatbi dvow choothatbale stbithow sesbow

One third of a troop of monkey with one third of itself has gone to the tank; the square root of the whole troop is afflicted with thirst, and the remaining 2 monkeys are sitting under the mango tree. What is the total number of monkeys? $\frac{1}{3}a + \frac{1}{9}a + \sqrt{a} + 2 = a$

REEDHARACHARYA - PATIGANTHA 990 AD

EQUATIONS OF HIGHER ORDER- II

बाले मरालकुलमूलदलानि सप्त तीरे विलासभरमन्तरगाण्यपश्यम् ।
कुर्वञ्च केलिकलहं कलहस्युग्मं शेषं जले वद मरालकुलप्रमाणम् ॥

*Bale maralakula mooladalaani saptha theere vilaasabhara
manthara gaanyapasyam kurvancha keleekalabam
kalabamsayugmam sesham jale vada maralakula pramaanam*

I saw that one half of 7 times of the square root of the total number of swans were slowly moving away in the river. Remaining 2 are playing in water. What is the number of total swans? (equation: $7/2 \sqrt{a} + 2 = a$)

BHASKARACHARYA - LILAVATI 1114 AD

PYTHAGORUS THEOREM DISCOVERED BY BOUDHAYANA

समचतुरश्रस्यक्षयारज्जुः द्विष्टावर्ति भूमिं करोति ।

Samachathurasrasyakshayaraajju: dvishthavathim bhoomim karothe

The diagonal of a square produces double the area of the square.

दीर्घचतुरश्रस्यक्षयारज्जुः पार्श्वमानि तिर्यन्मानि
घ यत्पृथग्भूते कुरुतस्तदुभयं करोति ।

*Deerghachathurasrasyakshayaraajju: paarsvamaani
thiryanmaani cha yatpruthagbhoothe kurutastbadubhayam
karoti*

Areas produced separately by the length and breadth of rectangle together equal to the area of the (square) produced by the diagonal.

BOUDHAYANA BOUDHAYANA SULBASUTRA 700 BC

EXPLANATION OF BINOMIAL THEOREM

If a three syllabic Madhya Chanda based on guru and lakhu sounds were followed, then variation of guru and lakhu sound will be on the following pattern: 3 guru sound occur once, 2 guru and 1 lakhu occur thrice, 1 guru and 2 lakhu sounds occur thrice, 3 lakhu occur once. The equation can be derived easily. If guru is g and lakhu is 1 then,

$(g+1)^3 = g^3 + 3g^2 \cdot 1 + 3g \cdot 1^2 + 1^3$. This equation is the same as $(x+y)^3$. Similarly for finding the pratishta Chanda, in the Chanda sastra of Pingalacharya, the following equation can be indirectly applied in this form: $(g+1)^4$ which is expanded as $g^4 + 4g^3 \cdot 1 + 6g^2 \cdot 1^2 + 4g \cdot 1^3 + 1^4$. I.e 4 guru sound occur once, 3 guru and 1 lakhu occur four times, 2 guru and 2 lakhu occur four times, 1 guru and 3 lakhu occur four times and 4 lakhu occur once.

PINGALACHARYA - CHANDASASTRA 200 BC

GEOMETRY IN SULBASUTRA-II

तासां त्रिकचतुष्कयोर्द्वादशिकपञ्चिकयोः पञ्चदशिकाष्टिकयोः
साप्तिकचतुर्विंशतिकयोः द्वादशिकपञ्चत्रिंशिकयोः
पञ्चदशिकषट्त्रिंशिकयोः इत्येतासूपलब्धिः ॥

*Tbaasaam trika chatbushkayordvaadasikapanchikayo:
panchadasikaasbti kayo: saaptikachathurimsathikayo:
dvaadasika panchathrimsthikayo: panchadasikasad-
thrimsthikayo: ityethaasoopalabdh:*

Hypotenuse in rectangles having sides 3 and 4 (= 5), 12 and 5 (= 13), 15 and 8 (= 17), 7 and 24 (= 25), 12 and 35 (= 37) and 15 and 36 (= 39) (1.49).

BOUDHAYANA BOUDHAYANA SULBASUTRA 700 BC

ANGULAR DIMENSIONS

अंगगुणवेदहुताशाः कलिका विकलाः समुद्रजलधयः
स्यत्पजलखाष्टशशि धृतिशशिनः कलिकाः शराग्नयो
विकलाः त्रिज्याकृतिरष्टनवत्रिभुवो विश्वे जिनांशज्या ॥

*Angagunavedabuthaasaa: kalikaa vikala: samudrajaladbaya:
svalpajalakhaashtasasi dhruthisashina: kalikaa: saraagnayo
vikala: thrifyaakruthivarashta navathribhuvoo visve
jinaamsajyaa.*

3436' 44" is radius and 11818047' 35" is square of radius and 1398' 13" is Rsin of 24° (both are values in radians).

VATESWARA- VATESWARA SIDDHANTA 880

TRIANGLES

त्रिभुजस्य फलशरीरं समदलकोटि भुजार्धसंवर्गः ।

Tribbujasya phalasareeram samadalakoti bbujardha samvarga:

The area of a triangle is the product of the perpendicular and half the base.

ARYABHATTA I ARYABHATEEYA 492 AD

कर्णस्त्रयोदश स्यात् पञ्चदशान्यो मही द्विसप्तैव ।
विषमस्त्रिभुजस्य सखे फलसंख्या का भवेदस्य ॥

*Karnastbrayodasa syaatb panchadasaanyo mabee drisapthaiva
visbamastbri bbujasya sakhe phalasankhyaa kaa bbavedasya*

What is the area of a scalene triangle in which one lateral side is 13 units, other 15 unit and the base is 14 units.

अष्टादशकोच्छ्रयो वंशो वातेन पातितोमूलात् ।

षड्गत्वासौ पतितास्त्रिभुजं कृत्वा क्व भग्नः स्यात् ॥

*Ashtaadasakocchrayovamso vaatbena paatithomoolaatb
shadgatbvaavasow patithaasthribhujam krutvaa kva bbaghna:
syaatb*

A bamboo of height 18 cubits fell by the wind, it falls at a distance of 6 cubits from the root, thus forming a right triangle, where is the break?

BRASKARA I COMMENTARY TO ARYABHATEEYA 628 AD

POLYGONAL

त्रिव्यङ्काग्निनभश्चन्द्रैस्त्रिबाणाष्टभिः वेदाग्निबाणखाश्चैव
खखाभ्राभ्ररसैः क्रमात् बाणेषुनखबाणैश्चद्विद्वि नन्देषुसागरैः
कुरामदशवेदैश्च वृत्तव्यासे समाहते खखखाभ्राक संभक्ते
लभ्यन्ते क्रमशोभुजाः वृत्तान्तस्त्र्यपूर्वाणां नवास्त्रान्तं पृथक् पृथक्

*Tbribdbyankaagninabha ischandraistbri bbaanaa
shayngaashtabbi. vedaagni baanakhaaschaicha kbakhaabbhraa
bbrarasai: kramaath baanesbu nakha baanaishchadvidvi
nandesbu saagarai: kuraamadasavedaishcha vruttbavyaase
samaahathe kbakhaabbhraarka sambaktithe labbhyantthe
kramasobbujaa: vruttbaantha sthaya poorvaanaam
navaasraantam pruthak pruthak*

For cyclic equilateral triangle, cyclic square, cyclic equilateral pentagon,... to cyclic equilateral nonagon, (cyclic figures having 3 to 9 sides with equal side measurements) their sides can be calculated respectively when diameter is multiplied separately with 103923 (triangle) 84854 (quadrilateral) 70534 (pentagon), 60000 (hexagon) 52055 (septagon) 45922 (octagon) and 41031 (nonagon) and divided by 120000, the value will be the measurements of the sides of cyclic equilateral triangles to cyclic equilateral nonagon. Bhaskaracharya has given the example: If 2000 is the diameter of circle, equilateral geometrical figures inscribed inside that circle will have sides as follows:

Geometrical figure	Bhaskara's value	Modern value
Triangle	1732 + .05	1732.043
Square	1414 + .021	1414.211
Pentagon	1175 + .056	1175.5619
Hexagon	1000 + .00	999.996
Septagon	867 + .58	867.5799
Octagon	765 + .36	765.3636
Nonagon	683 + .85	683.85

BHASKARA II - LILAVATI 1114 AD

CIRCLE - VALUE OF Π

चतुरधिकं शतमष्टगुणं द्वाषष्टिस्तथा सहस्राणां अयुतद्वय
विष्कम्भस्यासन्नो घृतपरिणाहः ।।

*Cbatburadbikam satbatmashtagunam dvaasbashtisthatbaa
sabasraanaam ayuthadvya vishkambasyaasannoo
vrutbhaparinaaha:*

When 100 increased by 4 multiplied by 8 and added to 62,000 gives an approximate value for the circumference of a circle having diameter 20,000 units.

ARYABHATA I ARYABHATEEYA 492 AD

अष्टद्वादशशब्दकाः विष्कम्भस्तत्त्वतो मया दृष्टाः । तेषां
समवृत्तानां परिधिफलं मे पृथक् ब्रूहि ।।

*Ashtadvaadasa shadkaa: vishkambasthatbvatho mayaa
drushtaa: tbeshaam samavrutthaanaam parithiphalam me
prutbak broohi*

Diameter of 3 circles are correctly seen by me to be 8, 12 and 6 units respectively. Tell me separately the circumference and areas of the circles.

BHASKARACHARYA I - 628 AD

SOMAYAJI'S THEOREMS

**व्यासाद् घनसंगुणितात् पृथगाप्तं त्रयाद्ययुग्मिमूलघनैः ।
त्रिगुणव्यासे स्वमृणं क्रमशः कृत्वापि परिधिरानेयुः ॥**

Vyaasaath vanaasangunithaath pruthagaaptam thryaadyayugmimoola ghanai: thrigunavygaase svamrunam kramasa: krutvaapi paridhiraaneyu:

Multiply the diameter of a circle with 4 and keep it at different places and divide each with the odd numbers beginning from 3, 5, 7, .. as their cubes subtracted by the same value. Repeat this and add/subtract alternatively the results to three times the diameter of the circle to get the circumference with the highest degree of accuracy. This theorem can be mathematically represented as follows:

$$\text{Circumference} = 3D + 4D/(3^3-3) - 4D/(5^3-5) + 4D/(7^3-7) \dots$$

**वर्गार्युजां वा द्विगुणैर्निरेकैर्बर्गाकृतैर्वर्जित युग्मवर्गैः ।
व्यासं च षड्जं विभजेत् फलं स्वं व्यासे त्रिनिष्णे परिधिस्तदास्यात् ॥**

Vargairyujaam vaa dvigunairnirekair vargeekrutbair varji tbayugma vargai: vyaasam cha chadgbnam vibbajeth phalam svam vyaase thrinibne paridhi sthadaasyaath

Six times the diameter is divided separately by the square of twice the square of even integers 2, 4, 6, .. minus one, diminished by the squares of even integers themselves. The sum of the resulting quotient by thrice the diameter is the circumference.

This can be mathematically written as follows: Circumference =

$$3D + 6D([(1/2 \times 2^2 - 1)^2 - 2^2] + [(1/2 \times 4^2 - 1)^2 - 4^2] + [(1/2 \times 6^2 - 1)^2 - 6^2]) + \dots$$

SMITHUMANA SOMAYAJI - KARANAPADDHATI 1450 AD

AREA OF CIRCLE AND SPHERE

वृत्तक्षेत्रे परिधिगुणितव्यासपादः फलं तत् क्षुण्णं
वेदैरुपरिपरितः कन्दुकस्येव जालं । गोळस्यैवं तदपि च
फलं पृष्ठजं व्यासनिघ्नं षड्भिर्भक्तं भवति नियतं गोळगर्भे
घनाख्यम् ।।

*Vruttbaksatre paridhigunitba vyaasapaada: phalam thath
ksbunnam vedairupari paritba.kandukasyeva jaalam
golasyatvam thadapi cha phalam prushtajam vyaasanighnam
shadbhirbhaktam bhavatbi niyatam golagarbhe
ghanaakhyam*

When circumference is multiplied with diameter
and that result divided by 4, that will give the area
of a circle. This when multiplied with 4 gives the
surface area of the globe which is like surface of a
ball. This when multiplied with diameter and
divided by 6 gives the volume of the sphere of globe.

Mathematically it can be written as $2\pi r \times 2r/4 = \pi r^2$

BHASKARACHARYA II - ILAVATI - 1114 A.D

NEWTON GAUSS (1670AD) BACKWARD INTERPOLATION DISCOVERED BY VATESWARACHARYA

धनुषाप्त भुक्त जीवघाते लब्धं सरूपकं दलितम् ।
लब्धघ्न विवरहतं च संशोध्य नियोज्य विकलज्या ।।

*Dhanushaapta bhukta jeevaghaate labdham saroopakam dalitam
labdagbna vivarabatham cha samsodhya niyogya vikalajyaa*

In modern mathematical form this interpolation
formula can be written as $f(x) = f(x_i) + (x-x_i)1/h$
 $Df(x_i-h) + (x-x_i)1/h \cdot (x-x_i+h)1/h \cdot D^2f(x_i-h)^{1/2}.$

VATESWARA VATESWARA SIDDHANTA 904 AD

ARC AND CHORD

स्वल्पचापच्छद्यनषष्ठभागतो विस्तारं कृतिर्भक्तवर्जितम् ।
शिष्टचापमिहशिञ्जनि भवेत् तद्युतोऽल्पकगुणोऽसकृत्धनुः ॥

*Svalpachapaacchadyanashashta bhaagatbo vistaraardhakruutir-
bhaktha varjitam sishtachapamibasinjanee bhaveth thadyuth
o falpaka guno fasakruithdhanu:*

The chord of an arc of a circle is obtained from the result of the cube of the length of the arc divided by six times the cube of radius and subtracted from the arc. This can be mathematically presented as follows: $\text{Chord (R Sine } \theta) = s - (s^3 / 6r^3)$. Here length of the arc s is in angular dimensions, r is the radius and θ is the angle of the arc.

PUTHUMANA SOMAYAJI - KARANA PADDHATHI - 1450 AD

परिधेः षड्भागज्या विष्कम्भाधने सा तुल्या ।

Paridhe: shadbbaagajyaa visbkambhaardhena saa thulyaa

The chord of one sixth of circumference is equal to the radius of that circle.

ARYABHATTA I - ARYABHATEEYA 499 AD

LENGTH OF ARC - CHORD

व्यासाब्धिघातयुतमौर्विकया विभक्तो जीवाङ्घ्रिपञ्चगुणितः
परिधेस्तुवर्गः । लब्धोनितात् परिधिर्वर्ग चतुर्यभागादाप्ते
पदे वृत्तिदलात् पतितेधनुः स्यात् ॥

*Vyaasaabdhighaatayutamauvikaaya vibhaktbo jeevaangbri
panchagunitha: paridbestbuvarga: labdhonithaatb
paridbivarga chaiburtha bhaagaadaapte pade vrutthidalaatb
patibhedbanu: syaath.*

One fourth of five times the chord multiplied with square of circumference divided by four times the diameter added with the chord. This value is subtracted from one fourth of the square of circumference. Square root of this is taken and subtracted from half of the circumference to get the arc.

BHASKARA II - LILAVATI 1114 AD

ARC AND ARROW

ज्याव्यासयोगान्तरघातमूलं व्यासस्तदूनो दलितः शरः स्यात् ।
व्यासाच्छरोनच्छरसंगुणा च मूलं द्विनिघ्नं भवतीह जीया ।
जीवार्धवर्गे शरभक्तयुक्ते व्यासप्रमाणं प्रवदन्ति वृत्ते ।

*Jyavvyaasayogaanthara ghaatbamoolam vyaasastbadoono
daitbha. sara: syaath vyaasaacchbaronaacchbara sangunaa cha
moolam dvinighnam bhavatbeebea geevaa yeevaardbavarge
sarabbaktba yukthe vyaasapramaanam pravadantbi vrutthe*

When the sum and differences of diameter and the chord are multiplied, and their square root is taken and if half of that is subtracted from the diameter, the arrow is obtained. The difference of diameter and the arrow multiplied with the arrow, twice the square root of that value gives the chord. The square of half the chord divided by arrow and added with arrow gives the diameter of the circle.

BHASKARA II - LILAVATI 1114 AD

**NEWTON'S INFINITE GP CONVERGENT SERIES
DISCOVERED BY NILAKANTA SOMAYAJI**

एवं यस्तुत्यच्छेद परमभाग परमपर्यया अनन्ताया अपि
संयोगः तस्य अनन्तानां अपि कल्प्यमानस्य योगस्य
आद्यावयविनः परस्परमच्छेदाद् एकोनच्छेदामंश साध्यं
सर्वत्रापि समानं एव.....

*Evam yasthuthya ccheda paramabhaaga paramaparyayaa
anantbaayaa api samyoga: thasya anantbaanaam api
kalpyamaanasya yogasyaaddhyaavayavina: parasparama
ccbedaad ekonacchedaa mamsa saadhyam sarvathraapi
samaanam eva...*

Thus the sum of an infinite series, whose later terms
(after the first) are got by diminishing the preceding
or by the same divisor, is always equal to the first term
divided by one less than the common mutual divisor.

NILKANTA ARYABHATEEYA BHASHAYA 1444

SINE, COSINE, RADIUS AND ARC

अन्योन्यकोटिहतयोरभिमत गुणयोस्त्रिजीवया हतयोः ।
योगवियोगौ स्यातामभिमतगुणचापयोगविवरगुणौ ॥

*Anyonya kotibatbayorabbimatha gunayostbrijeejavayaa
batbaya: yogaviryogow syaatbaamabbimathagunachaapa
yogavivaragunow*

The sum of the products of Sin A and Cos B and when angles are exchanged, Sin B and Cos A, gives the Sin of the sum of the angles. Similarly the difference of the above gives the value of the sin of angular difference. $\sin (A+B) = \sin A \cos B + \cos A \sin B$ And $\sin (A-B) = \sin A \cos B - \cos A \sin B$.

यद्वेष्टचापगुणत छरवर्गयोगमूलार्धमिष्टधनुरर्धगुणः प्रदिष्टः ।
ज्यानां निजत्रिगुणवर्गविशेषमूलं कोटिस्तद्वसस्तित्रिगुणैस्वभाणौ ॥

*Yadveshta chaapagunatba ccharavargayoga moolardhamishta
dhanurardhaguna: pradishta: ज्यानां निजत्रिगुणवर्गविशेषमूलं कोटिस्तद्वसस्तित्रिगुणैस्वभाणौ ॥*

Square root, of the square of a chord ($R \sin \theta$) diminished from squares of radius gives the koti ($R \cos \theta$). This subtracted from radius gives the (small) arrow of arc. This added to radius is big arrow of the arc.....

PUTHUMANA SOMAYAJI - KARANA PADDHATI 1450

TAYLOR (1685 AD) SERIES OF SINE AND COSINE DISCOVERED BY NILAKANTA

इष्टदोः कोटि धनुषोः स्वसमीपसमीरते ज्ये द्वे सावयवे
न्यस्य कुर्याद् ऊनाधिकं धनुः द्विघ्न तल्लिप्तिकाप्तैक शरशैल
शिखीनन्दवः न्यस्याच्छेदाय चमिथास्तत्संस्कार विधित्सया
चित्तयैकां प्रक्षिपेज्जह्यात् तद्धनुष्यधिकोणके अन्यस्यां
अथ तां द्विघ्नां तथार्त्स्यां इति सस्कृतिः संत ते कृत
संस्कारे स्वगुणौ धनुषास्तयोः

*ista-dohkotidhanusob svasamipasamirate jye dve saavayave
nyasya kuryaad unaadbhikam dhanub dvighna
talliptikaptaiikasarasailasikhindavah nyasyacchedaaya cha
mitbastatsamskaaraavidbitsaya anyasyam atba taam dvighnaam
tathaa syam iti samskriti: santba te krtasamskare svagunau
dhanusas tayo:*

Placing the sine and cosine chords nearest to the arc, whose sine and cosine chords are required, get the arc difference to be subtracted or added. For making the correction, 13,751 should be divided by twice the arc difference in minutes and the quotient is to be placed as the divisor, divide the one (sine or cosine) by this divisor and add to or subtract from the other (cosine or sine) according as the arc difference is to be added or subtracted. Double this result and do as before. Add or subtract the result to or from the first sine or cosine to get the desired sine or cosine chords.

NILAKANTA - TANTRA SANGRAHA 1444 AD

NEWTON GAUSS (1670) INTERPOLATION FORMULA DISCOVERED BY GOVINDASWAMI

गच्छाद्यात गुणान्तरवपुर्यातैष्य दिधासनाच्छेदाभ्यास
समूहकार्मुककृतिप्राप्तात् त्रिभिस्ताडितात् वेदैर्हिषड्भिर्
अवाप्तम् अन्त्यगुणजे राशयोः क्रमात् अन्त्यभेः गन्तव्याहक
वर्तमानगुणजाच्छापाप्तं एकादिभिः। अन्त्याद् उत्क्रमतः
क्रमेण विषमैः सङ्ख्याविशेषैः क्षिपेद्भङ्गत्वाप्तं, यदि
मौर्विकाविधिर् अयं माख्यः क्रमात् वर्तते शोध्यं
ष्युत्क्रमतास्तथाकृतफलं.....

*gacchad-yata-gunantaratavapuryatbaishya-disvasanaa
cchedaabhyaasa-samuba-kaarmukakrti-praaptbatb
tribhutbaaditbab vedatbi sadbbir avaaptam antyagunaje rasyo:
kramad antyabbe gantavaahata-varthamaana-gunajaaccha
paatbam ekaadibbi antyad utkramatab kramena visbamai.
sankhyavvishba. khsipedibhanktbraptam, yadi mairvikaradbbir ayan
makhyab kramad variate sodhyam vyakramanathaa natbadeitbapblam—*

Mathematically this formula is summarised as follows:
 $F(x+nh) = \Delta f(x) + nf(x) + \frac{1}{2}n(n-1)(\Delta f(x) - \Delta f(x-h))$ Multiply
the difference of the last and the current sine differences
by the square of the elemental arc and further multiply
by three. Now divide the result so obtained by four in
the first rasi, or by six in the second rasi. The final result
thus obtained should be added to the portion of the
current sine difference (got by linear proportion) In
the last rasi, multiply the linearly promotional part of
the current sine differences by the remaining part of
the elemental arc and divide by the elemental arc. Now,
divide the result by the odd numbers according to the
current sine difference, when counted from the end in
the reverse order. Add the final result thus obtained to
the portion of the current sine difference. These are
the rules for computing true sine differences for sines.
In the case of versed sines, apply the rules in the reverse
order and the above corrections are to be subtracted
from the respective differences.

GOVINDASWAMI - COMMENTARY FOR MAHABHASKARIEYA 900 AD

**NEWTON'S (1660 AD) POWER SERIES
DISCOVERED BY SOMAYAJI**

निहत्य चापवर्गेण चापं तत्तत् फलानि च हरेत्
समूलयुग्मवर्गैस्त्रिज्यावर्गहतैः क्रमात् चापं फलानि
चाधोधोन्यस्योपर्युपरि त्यजेत् जीवाप्त्यै, संग्रहोऽस्यैव विद्वान्
इत्यादिनाकृतः निहत्य चापवर्गेण रूपं तत्तत् फलानि च
हरेद् विमूलयुग्मवर्गैस्त्रिज्यावर्गहतैः क्रमात्
किन्तु व्यासदलेनैव द्विघ्नेनाद्य विभज्यतां फलान्यधोधः
क्रमशोन्यस्योपर्युपरि त्यजेत् शराप्त्यै, संग्रहोऽस्यैव
स्तेनस्त्रीत्या दिनाकृतः

*nibatya chapavargena chapam tattathphalani cha baret
samulayugvargaistriyavargahatai: kramaat chapam phalani
chadbodhonyasyoparyupari tyajet jivaptyai, sangrabo syaiva
vidvan-ityadina krtba: nibathya chapavargena rupam
tattatphalani cha bared vimulayugvargaistriyavargahatai:
kramat kintu vyasadalenaiva dvighnenadyam vibhajyataam
phalanyadbodha: kramaso nyasyoparyupari tyajet saraptyai,
sangrabo asyaiva stena-stri-tyadinaa krtba:*

Multiply repeatedly the arc by its square and divide by the square of even numbers increased by that number and then multiplied by the square of radius. Place the arc and result one below the other and subtract each from what is above it. To derive the arc, which are collected, beginning with the expression *Vidvan* (katapayadi number). Multiply repeatedly, the unit measurement which is the radius, by the square of the arc and divide by the square of even numbers decreased by that number and then multiplied by the square of radius; the first is, however, to be divided by twice the radius. Place the results one below the other and subtract each from the one above it. That is the method to derive the *saras*, which are collected in the beginning with *stena*. (This equation is now known as Newton power series.)

PUTHUMANA SOMAYAJI - KARANAPADDHATI (1450 AD)

VOLUMES OF CONES

समखातफलत्रयंशैः सूचीखाते फलं भवति ।

Samakhaatha phalatbryamasai: soobikbathe phalam bhavathi

The one third of the volume of the uniform cylinder is the volume of the cone.

परिधिभित्तिलग्नस्य राशोस्त्रिंशत्करः किला
अन्तकोणस्थितस्यापि तिथितुल्यकरः सखे । बहिष्कोण
स्थितस्यापि पञ्चघननय सम्मितः तेषामाद्यक्ष्य मे क्षिप्रं
घनहस्तात् पृथक् पृथक् ।।

*Pardbirbhittilagrasya raasestbrimsatkara: kila
anthakonasthitasyaapi tithitibulyakara: sakhe babishkona
sthitasyaapi panchaghnana sammita: teshaa ma chakshva
me kshipram ghanahastabha pruthak pruthak*

Friend, the food grains are kept at a circumference of 30 cubit in the floor, outside corner of the room, inside corner and side of the wall. Find out the volume of the grain if the height is 45 cubit.

SHANKARA B.LILAVATI 1114 AD

LHUIER'S (1782 AD) FORMULA

DISCOVERED BY SOMAYAJI

दोष्णाम्द्वयोर्द्वयोर्घातयुतानां तिष्ठाणां यद्घात्
एकैकोनेतरात्रैक्यं चतुष्कवधाभाजितं लब्धमूलेन यदवृत्तं
विष्कम्भार्धे निर्मितं सर्वं चतुर्भुजक्षेत्रं तस्मिन्नेव तिष्ठहते

*Doshnamdvayordvayor ghaatayutaanaam tisraanaam vadhaat
ekaikonetarattraiikyam catushkavadhabhantam labdha mulena
yadvarttam visbkambhaardhena nirmitam sarvam
caturbbujakshetram tasminneva tisthtabathe*

The three sums of the product of sides, taken two at a time are to be multiplied together and divided by the product of the sums of the sides taken three at a time and diminished by the fourth. If a circle is drawn with the square root of this quantity as radius, the whole quadrilateral will be situated inside it.

PARAMESWARA COMMENTARY FOR LILAVATI (1360 AD)

**GREGORY'S (1632 AD) SERIES
FOR INVERSE TANGENT**

DISCOVERED BY MADHAVA CHARYA

इष्टज्यात्रिज्ययोर्घातात् कोट्याप्तं प्रथमं फलं ज्यावर्गं गुणकं
कृत्वा कोटिवर्गं च हारकं प्रथमादिफलेभ्यो/धि नेया फल
कृतिर्मुहुः एक प्रयाद्योज संख्याभिरभक्तेष्वेतेष्वनुक्रमात्
ओजानां संयुतेस्त्यक्त्वा युग्मयोगं घनुर्भवेत् दोः
कोट्योरलपमेवेह कल्पनीयं इहस्मृतं लब्धीनां अवसानं
स्यान्न तथापि मुहुः कृते

*istajya-trijyayorgbatbat kotyaptam prathamam phalam
jyavargam gunakam kritva kotivargam cha baarakam pratha
maadipbalebhyo atba neya phalakrtir muhu: eka-tryaady-
ojasankhyabbirabbaktesbvetesbo anukramaat ojanam
samyutesthyaktva yugmayogam dhanur bhavet dob-kotyor
alpameveha kalpanyam sha smrtam labdbinam avasanam
syanna tbatbaapi muhu: krite*

Obtain the first result of multiplying the *jya* ($R \sin \theta$) by the *trijya* (radius) and dividing the product by *koti* ($R \cos \theta$). Multiply this result by the square of the *jya* and divide the square by the *koti*. Thus we obtain a second result a sequence of the further results by repeatedly multiply by the square of the *jya* and dividing by the square of the *koti*. Divide the terms of the sequence in order by the odd numbers 1,3,5, ; after this, add all the odd terms and subtract from them all the even terms (without disturbing the order of the terms). Thus is obtained the *dhanus* whose two elements are the given *jya* and *koti*. (Here the smaller of the two elements should be taken as the *jya*, since other wise the series obtained will be non finite) (use of Tangent)

MADHAVA YUKTI BHASHA? (1350 AD)

LEBNITZ (1673 AD) POWER SERIES

DISCOVERED BY SOMAYAJI

व्यासे वारिधि निहते रूपहते व्यास सागराभिहते त्रिशरादि
विषमसंख्याभक्तमृणं स्वं पृथक् क्रमात्कुर्यात् ।।

*vyase varidhi-nibate rupabrate vyasasaagaraabbihate tri-sara
adi\ vishamasankhya-bhaktamnam svam pruthak kramat karyat*

Multiply the diameter by 4. Subtract from it and add to it alternately the quotients obtained by dividing four times the diameters by the odd integers 3, 5, 7,.... This will give the fine value of the circumference i.e $\pi/4 = 1-1/3+1/5-....$

PLUTHUMANA SOMAYAJI - KARANAPADDHITI (1440 AD)

DE MOIVRE'S (1650 AD) APPROXIMATION DISCOVERED BY MADHAVA CHARYA

अस्मात् सूक्ष्मतरोऽन्यो विलिख्यते कश्चनापि संस्कारः अन्ते
सम संख्यादलवर्गसैको गुणः स एव पुनः । युगगुणितो
रूपयुतः समसंख्यादलहतो भवेद् हरः त्रिशरादि विषमसंख्या
हरणात् परं एतत् एव वा कार्यम् ।।

*Asmat suksmataroanyo vilikhyate kashcanapi samskara: ante
samasankhyadalavarga saiko guna:, sa eva puna. yugagunito
rupayuta: samasankhyadalabato bhaved haara: trisaradivisa
masbankhyabaranat param etad eve va karyam*

A correction for circumference still more precise is being stated here. The multiplier is the square of half the even integer increased by unity. This multiplier multiplied by 4, then increased by unity and then multiplied by half the even integer is the divisor. This correction may be applied after the division by odd integers, 3, 5, etc. i.e Circumference
$$= 4D (1-1/3+1/5-1/7+... + ..-1/n(1/2(n+1)^2+1 \div ((1/2(n+1)^2 \times 4 + 1) (1/2(n+1)))$$

MADHAVA KRIYA KRAMAKARI (1350 AD)

DE MOIVRE'S (1650 AD) APPROXIMATION

यत्संख्याया/त्र हरणे कृते निवृत्ताहृतिस्तु जामितया तस्या
ऊर्ध्वगतास्यास्मसंख्या तदलं गुणे/न्ति स्यात् तद्वर्गैरुपहतो
हारो व्यासाध्याततः प्रग्वत् तस्यां आप्तं स्वमृणे कृते
घने शोधनान्च करणीयं सूक्ष्मः परिधिः सा स्यात् बहुकृत्यो
हरणतो/तिसूक्ष्माश्च

*yatsankhyaatra harane krte nivrtta hr̥tis tu jamitaya tasya
urdhvagatasyas samasankhya taddalam guno ante syat
tadvargai rupahato haaro vyasadbhigbatata: pragvat tasyam
aptam svamrne krte dbane sodhanan cha karaniyam suksma:
paridhi. sa syat bahukrtvo haranato atisuksmas cha*

..... Let the process stop at a certain stage, giving rise to a finite sum, multiply four times the diameter by half the even integer subsequent to the last odd integer used as divisor and then divide by the square of the integer increased by unity. The result is the correction to be added to or subtracted from finite sum. The choice of addition or subtraction is depending on sign of the last term in the sum. The final result is the circumference determined more accurately than by taking a large number of terms:

MADHAVA YUKTIBHASHA? (1350 AD)

HORIZON

आवेष्टमानमथ तानि दलप्रवृत्त्या यद्वृत्तमत्र हरिजं क्षितिजं
तदाहुः यस्मिन् भवेत् समुदयोस्तमयोऽखिलानां प्राच्यां
क्रमादपरदिश्युद्धेचराणां

*Aaveshtamaanamatba tbaani dalapravruthyaa
yadurutthamatbra harijam kshitbijam tbadaahu: yasmin
bbavetb samudayaastbamayo akhilaanaam praachyaam
kramaadaparadisryudn kbecharaanaam*

The great circle which goes round them, dividing each of them into two equal parts, is called harija or kshitija. This in modern astronomy is horizon. This is the circle on which rising and setting of stars and planets take place towards east and west respectively.

VATESWARA SIDDHANTA 880 AD

ASTRONOMICAL DEFINITIONS

ऊर्ध्वमधोऽपरपूर्वमिहाद्यं प्राहुरिदं सममण्डलमन्यत् ।
तद्वदिहोत्त रदक्षिणदिक्स्थं वृत्तयुगं विदिशोरपि तद्वत् ॥

*Urdhvamadbo apara poorvamibaadyam praahuridam
samamandala manyatb tbadvadibottbara dakshinadikstham
vruttbayugam vidisorapi tbadvatb*

Vertical circle passing through the west and east cardinal points is the first circle: this is called the samamandala. (This circle is the prime vertical. Another similar vertical circle (called the yaamyottara-vrutta) which passes through the north and south cardinal points is called the meridian.

VATESWARA - VATESWARA SIDDHANTA 880 AD

**TYCHO BRAHE REDUCTION OF ECLIPTIC
DISCOVERED BY ACHYUTA PISHAROTI**

पातोन्स्य विधोस्तु कोटिभुजयोर्जीवे मितस्ताडयेत्
अन्त्यक्षेप शराहतं यधममुं विक्षेपकोट्याहरेत् । लब्धं
व्यासदलोद्धृतं हिमकरे स्वर्णं विपाते विधौ
युग्मायुग्मपदोपगे विधुरयस्स्पष्टो भगोले भवेत् ॥

*Patonasya vidhostu kotibbhujayorjive mitbastadayet
antyakshepasarahatam vadhnamam vikshepakotyaharet
labdham vyasadaloddhrtam himakare svarnam, vipate vidbau
yugmaayugmapadopage; vidburayam spashto bhagole bhavet*

Multiply the tabular cosine and sine of the moon minus node and the product by the tabular versine of the maximum latitude of the moon. Divide this by the tabular cosine of the latitude at the particular moment and the quotient is to be divided again by the tabular radius. The result is to be added to or subtracted from the moon's longitude, as the moon minus node is in an even or an odd quadrant, respectively. The true moon measured on the ecliptic is thus obtained.

ACHYUTA PISHAROTI SPHUTANIRNAYA

EQUATOR

खस्वस्तिकाद् दक्षिणतोक्षभागौ पाता(ल) संज्ञाच्च
तथोत्तरेण । नाड्यङ्कितं वैषुवतं तदुक्तं वृत्तं भगोलस्य
खगोलमध्ये ।।

*Khasvastbikaad dakshinatokshabhaagow paatbaa (la)
samjnachha thathottbarena naadyankitham vaisbuvatham
thaduktam vruttham bhagolasya khagolamadbye*

The sphere of the asterisms lie within the sphere of the sky. Great circle of the sphere of asterisms which lies towards the south of the zenith by an amount equal to the degrees of local latitude and towards the north of nadir by the same amount and which is graduated with the division of nadis is the vishuvathvrutta. This circle is called the equator.

VATESWARA SIDDHANTA 880 AD

6 O'CLOCK CIRCLE

पुर्वापरक्षितिजसङ्गमयोगतज्ज्व याम्यादधः पललवैः क्षितिजा
द्विलग्नं सौम्यादधोपरि समध्रुवमार्ग संस्थमुन्मण्डलं
दिननिशोः क्षयवृद्धिकृतात्

*Poorvaaparaksbithija sangamayorgatbamcha yaamyadadha:
palalavai: ksbithijaadvi lagnam soumyaadathopari
samadruvamarga samstham unmandalam dinaniso:
ksbayavruddhikruthaath.*

Passing through the two points of intersection of prime vertical and horizon, lying below the south cardinal point by the degrees of local latitude, fastened to the horizon, and lying above the north cardinal point, passing through the north celestial pole, is the Unmandala, the cause of decrease and increase of the day and night. (This in modern astronomy is known as the 6'o clock circle.)

VATESWARA SIDDHANTA 880 AD

CIRCLE OF DIURNAL MOTION

हरिजे परपूर्वमण्डलद्युज्यावृत्तविशेषशिज्जिनी ।

उदयाग्रगुणो धुमण्डले भूज्योदवृत्तकुजान्तरांशजीवाः ।।

*Harije parapoorva mandala dyujaavruthba visesha sinjinee
udayaagraguno dyumandale bhoojyotbavruttha kujaan
tharaamsajeevaa:*

R sine of the arc of the horizon lying between the prime vertical and the diurnal circle of the planet is the R sine of agra (now known as the rising point of the planet) and the R sine of the degrees of diurnal circle lying between six o' clock circle and the horizon is bhoojya (bhujya) which is termed as Earthsine.

VATESWARA SIDDHANTA 880 AD

DAY RADIUS

क्रान्तिज्यावर्गोनात् त्रिज्यावर्गात्पदं द्युजीवा स्यात् । त्रिज्याक्रान्तिज्यान्तरसमासघातस्य मूलं या ।।

*Kraanthijyaa vargonaath thrijyaavargaath padam dyujeevaa
syaath thrijyaakraanthi yaantbara samaasa gbaathasya moolam
vaa*

Day radius is equal to the square root of the difference obtained by subtracting the squares of R sine of the declination from the square of the radius or the square root of the product of the difference and the sum of the radius and the R sine of the declination.

VATESWARA SIDDHANTA 880 AD

ECLIPTIC

नाड्याहववृत्तो/जितुलादिलग्नं जिनांशकैर्दक्षिणतो मृगादौ ।
सौम्ये शीतमन्दिरादावपक्रमाख्यं तदुशन्ति वृत्तम् ॥

*Naaddyaahvavrutthaajatlulaadilagnam
jinaamsakairadaksbinatho mrugaadow soumye seetha
mandiraadaav apakramaakhyam thadusantbi vruttbam*

Fastened to the so called nadivrutta or the equator at the points of Aries and Libra and lying 24 degrees of the south (of equator) at the first point of Capricorn and 24 degrees to the north (of equator) at the first point of Cancer, there is a great circle called the apakrama vrutta (now known as the ecliptic)

VATESWARA SIDDHANTA 880 AD

DAY DIAMETER

विषुवज्ज्या/यामर्धवर्गविश्लेषमूलमवलम्बकः । क्रान्तित्रिज्या
कृत्योरन्तरपदं द्विगुणं दिनव्यासः ॥

*Visuvajjyaa aayaa mardha varga vislesha moolamavalambaka:
krantibitrijyaaakrutbyo rantharapadam dvigunam dinavyaasa*

Square the sine of latitude and deduct from the square of the radius. Its square root is the sine of the co-latitude (its arc being the co-latitude). Square the sine of the declination deduct from the square of the radius and find its root. Twice the result is the day diameter.

PANCHASIDDHANTIKA 4-23 - VARAHA MIHIRA 505 AD

SETTING POINT OF ECLIPTIC

प्राच्यांकुजापक्रमवृत्तसङ्ग प्राग्लग्नमाहुः (परितोऽस्ति लग्नं) ।
(लग्नादभवेत्) स (प्ते) म (रा) शि (र) स्त तस्या (स्त)
कालो भ्युदयो स्य भूयात् ॥

*Praachyaam kuja apakrama vrutthasanga praaglagnamaabu
(paritbo asthalagnam) (lagnaadbhaveth) sa (pta) ma (raa) si (ra)
stha thasyaa (stha) kaalo abhyudayasya bhooyath*

Point of intersection of horizon and the ecliptic in the eastern half of the celestial sphere is called praglagna. I.e. the rising point of ecliptic; the same in the western half is called astalagna, known as setting point of ecliptic.

VATESWARA SIDDHANTA 880 AD

RISING - SETTING LINE

व्यासार्धवृत्तेऽन्तरमेतयोः स्याच्चरार्धजीवा परपूर्वयोस्तत् ।
अग्राग्रयोर्यद् हरिजे निबद्धं सूत्रं ग्रहाणामुदयास्त संज्ञम् ॥

*Vyaasaardha vrutthe antarbaram etbayo: syaacchbaraardha jeevaa
parapoorvayosthath agraagraoryad harijenibaddham
soothram grabaanaam udayaastha samjnam*

The arcual distance between the six o'clock circle and the horizon measure, along the R circle trijyavrutta known as great circle of the celestial sphere, supposed to be of radius 3438' (minute of angle) is the charardhajya. It is called the R sine of the Ascensional difference. A thread tied to the extremities of the agra on the eastern and western halves of the horizon is called the udayaastasutra. (In modern astronomy it is known as the rising - setting line of planets).

JESWARA SIDDHANTA 880 AD

DAY RADIUS AND EARTHSINE

क्रान्तित्रिभान्तरज्या धुज्या वा चरदल जीवया हुता
त्रिज्याक्षिति जीवघ्ना स्वाहोरात्रार्धजीवा वा ।।

*Kraanti tribhaantbarajyaa dhyujyaa vaa charadalajeevayaa
brutbaa tbrijyaa ksbitbi jeevagbnaa vaaboraathbraardhajeevaa
vaa*

Rsine of the difference between the three signs and the declination is also equal to the day radius. Day radius multiplied by earthsine and divided by the R sine of the Ascensional difference gives the day radius.

VATESWARA SIDDHANTA 3(4)-3 - 880 AD

SUN'S PRIME VERTICAL

ऊर्ध्वमधोऽपरपूर्वमिहाद्यं प्राहुरिदं सममण्डलमन्यत् ।
तद्वदिहोत्तरदक्षिणदिक्स्थं घृत्तयुगं विविशोरपि तद्वत् ।।

*Urdhvamadho aparapoorvamihadyam praahuridam
samamandala manyath tadvathibottharadaksbina dikstham
vrutthayugam vidisorapi tadvath.*

Vertical circle passing through the west and east cardinal points is the first circle called samamandala or the prime vertical.

VATESWARA SIDDHANTA- GOLA. 3-1. 2 - 880 AD

PARALLAX-I

तिथेर्नतस्य क्रमशिञ्जिनी हता खमध्यलग्नप्रभवेन शङ्कुना ।
क्षमाषडङ्काब्धिशराङ्कनेत्रहृद् बिलम्बने स्याद् घटिकादि
वा फलम् ॥

Tithernathasya kramasinjanee hatbaa khamadhyalagnaprabhavana sankunaa kshamaasbadangkaabhi saraankanetbrabrud vilambane syaad ghatikaadi vaa phalam.

R sine of the hour angle at the amavasya multiplied by R sine of the altitude of the meridian ecliptic point and divided by 2954961 gives the parallax in ghatikas at mid eclipse (Sishyadhi vruddhi Tantra 6-8)

LALLACHARYA SISHYADHI VRUDDHI TANTRA

PARALLAX-II

त्रिराशिजीवा चलनज्यका हता शिलीमुखैरङ्गुलतां व्रजन्ति ताः
द्विसङ्गुण दृष्टिगतिः शराचलैर्विभाजिता लम्बननाडिका फलम्

Tbriraasijeevaa valanajyaka hatbaa shileemukkbair angulatbaam vrajanthi thaa: dvisankunaa drushtigathi: saraachalairvibhaajitbaa lambana naadikaa phalam

Radius and the valanajya when divided by 5, are converted into angulas. The R sine of driggati multiplied by 2 and divided by 75 gives ghatika of the parallax in longitude. (Sishyadhi vruddhi Tantra 13-11)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

PARALLAX-III

नतक्रमज्याम्बरशङ्कुनिघ्ना स्याल्लम्बनं तत्परसेषुहृद्वा
दक्षेप भुक्त्यन्तरयोश्च घातः खबाणयुग्मक्षिप्तो नतिः स्यात्

*Natbakramajyaambara sankunighnaa syaallambanam
thatbvarase shubrudvaa drukshepabhuktbyantbara yoscha
ghaatba: khabaanayugmaa ksbihrutho natbi: syaath*

R sine of the hour angle multiplied by Rsine of altitude of the meridian ecliptic point and divided by 5625 gives parallax in longitude. The Difference of true motions of the Sun and the moon multiplied by the Rsine of drukshepa and divided by 2250 gives the parallax in latitude. (Sishyadhi vruddhi Tantra 13-12)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

APOGEE, PERIGEE AND ORBIT OF EARTH.

स्वोच्चात् षड्भागाध्यधिको यदा तदा भवति स्वनीचस्थः ।
दूरेणोच्चग उर्व्याः कर्णवशान्नोच्चगो निकटे ॥

*Svochbbaath shadbbaagaadhyadbiko yadaa thadaa bhavathi
svaneechastha: doorenochbaga urvyaa: karnavasaannochbhago
nikate*

When a planet is at a distance of 6 signs from its apogee, it is said to be at the perigee or neecha. When a planet is at the apogee, it is farthest from the earth when at the perigee, it is nearest to the earth. This is so because of the length of the hypotenuse in each case (Sishyadhi vruddhi Tantra 14-10)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

VELOCITY OF PLANETS PER DAY

गोपाज्ञया दिनधाम Sun 59' 8" 10''' 13'''
(*gopaaajnayaa dinadbaama*)

चण्डिकेशो भर्ग स्निग्धोसौ Moon 790' 34" 51''' 36'''
(*Chandikesa bharga snigdho:au*)

प्रभुर्धराचक्रपालः Mars 31' 26" 29''' 42'''
(*Prabhurdharaachakra paala*)

रागीतुम्बुरुर्गणेश्वर Mercury 245' 32" 36''' 32'''
(*Rageetbumbururganeswara*)

प्रज्ञासन्नो धर्मवान् Jupiter 4' 59" 7''' 2'''
(*Prajnaasannoo dharmavaan*)

काशी साम्बसन्न चोळः Venus 96' 7" 37''' 51'''
(*Kasi saambasanna chola:*)

प्रबलप्राज्ञो नरः Saturn 2' 0" 23''' 32'''
(*Prabhalapraajno nara:*)

The modern values of angular motions are Earth/
Sun 59.14', Mars 31.45', Mercury 245.7', Jupiter 4.99'
Venus 96.13', and Saturn 2'.

PUTHUMANA SOMAYAJI KARANAPADHATI (1450 AD)

SHAPE OF EARTH

गगनमरुदाग्निजलमृण्मयो महाभूतगुणयुतः स्वस्थः ।
कक्षाभिरावृतोऽयं भपञ्जरान्तश्च भूगोलः ॥

*Gaganamarudaagni jalamrunmayo mabaabbootba
gunayutba:kbastba: kakshaabbhiraavrutbo ayam bbapan
charaanbhascha bboogola*

Spherical earth, made of ether, fire, air, water and clay (Panchabhoothas) and thus have all the properties of the five elements, surrounded by the orbits and extending upto the sphere of stars, remain in the space (Sishyadhi vruddhi Tantra 17-1)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

प्रगुणःपरिधेः शतांशको गणितज्ञाः कथयन्ति दृश्यते ।
प्रतिभाति तदा समा मही विषये यत्र तथैव गम्यते ॥

*Praguna paridhe. satbaamsako ganithajnaa: kathayanti
drusyatbe prathi bhaatbi tbadaa samaa mabee visbaye yanthra
tbathaiva gamyatbe*

Mathematicians say that one hundredth of the circumference of the earth appears to be plane. So, that portion of the earth appears to be plane to an observer (Sishyadhi vruddhi-Tantra 20-35)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

ROTATION OF EARTH - I

प्राणेनैति कलां भूयीदि तर्हि कुतो व्रजेत् कमध्यानम्
आवर्तन मुव्याश्चेन्न पतन्ति समुच्छ्रयाः कस्मात् ।।

*Pranenaithi kalaam bhooryadi tharbi kutbo vrajeth
kamadbhyaanam aavarthana muroyaa scbenna patbantbi
samuccchrayaa: kasmath*

If earth rotates at a speed of 1' of an angle in 4 seconds, will not the things on the loft fall? Where does the earth go in this speed? (Brahmasphuta siddhanta 11-17).

BRAHMAGUPTA BRAHMASPHUTA SIDDHANTA 629 AD

FOUR QUADRANTS OF EARTH

उदयो यो लङ्कायां सोऽस्तमयः सवितुरेव सिद्धपुरे ।
मध्याह्नो यवकोट्यां रोमकविषयेऽर्धरात्रं स्यात् ।।

*Udayo yo lankaayaam soasthamayo: savitbureva siddbapure
madhyabno yavakotyaaam romake vishaye ardbaraathramsyaath*

When it is Sunrise in Lanka, the same Sun sets in Siddhapura. (Gautimaala). It is noon in Yavakoti (Korea) and midnight in Romaka (Rome) (Aryabhateeyam 4-13).

ARYABHATA -I ARYABHATEEYA (499 AD)

GLOBE

समवृत्तपृष्ठमानं सूक्ष्मं गोलं प्रसाध्य दारुमयं स्थगितार्क
समाङ्कितकाल भोगरेखाद्वये परिधौ ।।

*Samavruttbaprusbtamaanam sookshmam golam prasaadbya
daarumayam sthagitbaarka samaankitha kaala
bbogarekaadvaye paridhau*

Perfectly circular throughout and spherical, made of wood, marked with degrees and minutes, incorporated with lines both longitude and latitude at ends, is the golayantra. (Panchasiddhantika 14-23)

VARAHAMIHIRA PANCHASIDDHANTIKA (505 AD)

काष्ठमयं समवृत्तं समन्ततः समगुरुं लघुं गोलं
पारदतैलजलैस्तं भ्रमयेत् स्वधिया च कालसमं ।।

*Kaasbtamayam samavruttbham samantbatha: samagurum
laghum golam paaradatbaila jalaistham bbramayeth swadbiyaa'
cha kaalasamam*

Made of wood, fully circular, uniform, equally dense throughout and spherical shaped golayantra, which rotates at a fixed rate of time as the earth does by the help of mercury, oil and water, by the application of our intelligent calculation, is the golayantra-Globe.

नृषियोजनं, ञिला भूव्यासो

Nrusbiyojanam, njilaa bboovyaaso

8000 Nr units is equal to one yojana. The diameter of earth is 1050 yojana.

ARYABHATA-I ARYABHATEEYA (499 AD)

ROTATION OF EARTH - II

कु डि शि बु ण्लु षु ख् प्राक्

Ku ngi si bu nlu shru kbru praak

Eastward rotations of the earth in one Yuga is
1582237500

अनुलोम गतिर्नोस्थः पश्यत्यचलं विलोमगं यद्वत् ।

अचलानि भानि तद्वत् समपश्चिमगानि लङ्कायाम् ॥

*Anulomagatbirnoustha: pasyatbyachalam vilomagam yadvatb
achalaani bhaani tadvatb samapashchimagaani lankaayaam*

Just as a man in a boat moving forward sees the stationary objects as moving backward, so are the stationary stars and celestial bodies seen by the people at equator (Lanka) as moving exactly towards west.

.....कु आवर्ताश्चापि नाक्षत्राः ॥

Ku aavartshaaschaapi naakshatbraa:

The rotation of the earth is the cause of days
(Aryabhateeyam 3-5).

ARYABHATA-I ARYABHATEEYA (499 AD)

MERIDIAN

लङ्कायामेकं शङ्कुकीलं प्रतिष्ठाप्य तेनैकं सूत्राग्रं बद्ध्वा
पुनर्मैरोरुपरि तदग्रमन्यत् बद्ध्वा यथा यथा दृश्यते....
तद्वत् भूमावपि काचिद्रेख । लङ्कातः खरपुरतः मेरुमस्तकान
वगाह्य स्थिता सा पुनरत्रा-देशान्तरविधायिनी स्यात् ।।

*Lankaayaamekam sankukeelam prathishtaapya thenaikam
sootbraagram baddhvaa punarmerorupari thadagramanyath
baddhvaa yathayathaa drusyatba..... thadvatb bhoomaavapi
kaachidrekha lankaatba: kharapuratha.....
merumastbakaanaavagaabya stbubaa saa punarathra desaanthara
vidbaayini syaath*

Fix a pole in Lanka, tie thread on that, take the other end to the North pole, tie it there also, then one can see the line of the thread passing through Lanka, Kharapuri, Arctic point and so many other countries upto the top of Meru. This is international meridian line (Sankaranarayana on Laghubhaskareeya I-23)

SANKARANARAYANA I LAGHUBHASKAREEYA (950 AD)

GRAVITY

आकृष्टिशक्तिश्च मही तया यत् खस्थं गुरु स्वाभिमुखं
स्वशक्त्या । आकृष्यते तत्पततीव भाति समे समन्तात्
क्व पतत्ययं खे ॥

*Aakrushti sakthischa mabee thayaa yath kbastham guru
svaabbimukham swasaktyaa aakrusbyathe thatbpathatbeeoa
bbaatbi same samanthaath kva pathatbyayam kbe:*

This earth attracts whatever solid materials are in the space, by her own force of attraction towards her (earth). All those subjected to this attractive force fall, to the earth. Due to equal force of attraction among the celestial bodies, where can each among them fall? (Siddhanta siromani Bhuvanakosham 6)

BHASKARA II SIDDHANTA SIROMANY (1114 AD)

MERIDIAN AND TIME

देशान्तरघटीक्षुण्णा मध्या भुक्तिर्धुचारिणां षष्ट्या भक्तमृणं
प्राच्यां रेखायाः पश्चिमे धनम् ।।

*Desaanthara gbatee ksbunnab madbyaa bbukthir
dyuchaarinaam shasbtyaa bbaktbam runam praachyaam
rekbaayaa: paschime dhanam.*

The time is calculated based on the meridian. Divide the time by 60... and the longitude is calculated. Towards the east subtract and towards the west add the number (Laghubhaskareeyam 1-31)

BHASKARA I. LAGHUBHASKAREEYA (628 AD)

MERIDIAN AND TIME

पञ्चाशता त्रिभिस्त्रयंशसंयुतैर्योजनैश्च नाड्येका । समपूर्वं
पश्चिमस्थैर्नित्यं शोघ्या च देया च ।।

*Panchaasathaa thribbisthryamsaamyutbairyojanaishcha
naaddyekaa samapoorva paschimasthairnithyam sodhyaa cha
deyaa cha*

One nadi for every 53 1/3 yojanas has to be deducted or added (to Ujjaini) by the people in places east and west, respectively of the Ujjaini meridian. (Panchasiddhantika 9-10)

VARAHAMIHIRA - PANCHASIDDHANTIKA (605 AD)

ECLIPSE-I

किमर्थंअसुरः कश्चिद्राहुर्नाम सैहिकेयो/र्कि चन्द्रं च ग्रसत
इतिश्रूयते। सपि पौराणिक श्रुतिरेव ! कः पुनरिह
राहुरित्युच्यते।।

*Kimartham asura: kaschidraaburnaama saimbikeyoarkam
chandram cha grasatha itbi srooyatbe sraapi pouraanika
srutbireval ka: punariha raahurithyuchbyathe*

What does it mean that Asura is responsible for the eclipse? Others say that a snake Rahu swallows the Sun and the Moon! Those are puranic stories! Then what is called the Rahu?

**SANKARANARAYANA COMMENTRAY TO
LAGHUBHASKAREEYA 950 AD**

छादयति शशी सूर्यं, शशिनं महती च भूच्छाया।

Cchadayathi sasi sooryam sasinam mabathee cha bboocchaayaa

Moon covers (shadows) the Sun and the great shadow of the earth covers the moon (which causes the eclipse)

ARYABHATAI ARYABHATEEYA (499 AD)

ECLIPSE-II

अत एव भूच्छाया चन्द्रग्रहणस्य कारणं

Atha eva bhoocchayaa chandragrabhanasya kaaranam

That is why it is said that the shadow of the earth is the cause for the lunar eclipse.

SANKARANARAYANA COMMENTARY TO LAGHUBHASKAREEYA

असुरो यदि मायया युतो नियतो/तिग्रसतीति ते मतम् ।
गणितेन कथं स लभ्यते ग्रहकृत्पर्यं विना कथञ्चन ।।

*Asuro yadi maayayaa yutho niyatho athigrastbeethi they
mantam ganithena katham sa labhyathe grabakrutha
parva vinaa kathamchana*

If you are of the opinion that an artificial demon is always the cause of an eclipse by swallowing, then how is it that an eclipse can be determined by means of calculations. Moreover why is then not an eclipse occur on a day other than the day of new or full moon (Sishyadhi vruddhi Tantra 20-22)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

We are waiting for your unbiased and scientific views !

We submit with proof these claims, on the discoveries and inventions of the facts mentioned in this book, to the scholars and scientists. We request you to inform us your opinion and views on these claims, that these are INDIAN DISCOVERIES / INVENTIONS.

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